Tsuneo FUNAMOTO* & Hiroshi YUASA**: Karyological studies on diploid species of the section Telephium of *Sedum* in Japan

船本常男*・湯浅浩史**：日本産マンネングサ属ベンケイソウ節の二倍体種における核学的研究

The section (or subgenus) Telephium includes about 25 species which are represented from Europe to East Asia and one species in North America. Among them about 11 species occur in Japan from Hokkaido to Kyushu. *Sedum spectabile* native in China has been cultivated in Japan.

Previously, chromosome numbers of the section Telephium were reported in about 20 species by Sugiura (1931, 1937), Toyohuku (1935), Soeda (1944), Baldwin (1935, 1937), Jalas & Rönkkö (1960), Uhl & Moran (1972), and Funamoto & Yuasa (1986), of which $2n=20$, 22 and 24 chromosomes were counted on twelve diploid species. Chromosome numbers of all the Japanese species were observed and five diploid species (*Sedum pluricaule* var. *yezoense*, *S. verticillatum*, *S. telephium*, *S. sordidum* and *S. viride*) were found to have $2n=22$ and 24 chromosomes (Sugiura 1931, 1937, Toyohuku 1935, Soeda 1944, Baldwin 1937, Uhl & Moran 1972, Funamoto & Yuasa 1986). However, these studies reported only chromosome numbers and no karyological relationships among them, though Baldwin (1937) reported simply karyotypes of the five species.

This paper reports a result of karyotype analysis on the four diploid species of the section Telephium in Japan except *S. telephium*, and discusses the relationships and basic numbers among these species. We could not observe a good metaphase of *S. telephium*.

Materials and methods The plants investigated are listed in Tab. 1. These materials were collected in the field, and cultivated at the Research Institute of Evolutionary Biology. The observations of mitotic chromosomes

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Tab. 1. Chromosome numbers and localities of the diploid species of the section Telephium of *Sedum* in Japan.

Species	Chromosome number (2n)	No. of clone	Locality
S. pluricaule ssp. *pluricaule* var. *yezoense*	22	1	Hokkaido: Tokachi Prov., Asyoro-gun, Asyoro-cho
S. pluricaule ssp. *hidakanum*	22	2	Hokkaido: Hidaka Prov., Saru-gun, Hidaka-cho, Miiwa
S. verticillatum	22	3	Hokkaido: Abashiri Prov., Monbetsu-gun, Shiratori-mura
		2	Hokkaido: Hidaka Prov., Horoizumi-gun, Erimo-cho, Syoya
		1	Hokkaido: Hidaka Prov., Saru-gun, Hidaka-cho
		1	Tochigi Pref.: Nikko city, Unryu-kyo
S. sordidum	24	1	Aomori Pref.: Kamikita-gun, Towada-cho
		1	Fukushima Pref.: Date-gun, Hobara-cho, Mt. Amagoi
		1	Niigata Pref.: Minamiuonuma-gun, Muika-machi, Mt. Hakkai
		1	Nagano Pref.: Chiisagata-gun, Maruko-cho
		1	Nagano Pref.: Hanishina-gun, Sakaki-cho
S. viride	24	1	Gifu Pref.: Kamo-gun, Shirakawa-cho
		1	Fukui Pref.: Ohwi-gun, Takahama-cho, Mt. Aoba
		1	Tokushima Pref.: Mt. Tsurugi
		1	Ehime Pref.: Mt. Ishizuchi

were made from the meristematic tissues of root tips. These materials were pretreated with cold water for 8 hrs at about 4°C and fixed in Famer's solution (ethyl alcohol: acetic acid=3:1). Then they were stained with 2% aceto-carmine for about 2 hrs and squashed after maceration.

The chromosomes were designated according to Levan et al. (1964) based on the position of centromers.

Observations The results of chromosome counts on five taxa are shown in Tab. 1.

1) *Sedum pluricaule* ssp. *pluricaule* var. *yezoense* (Miyabe et Tatewaki) Tatewaki et Kawano, $2n=22$ (Fig. 1A & 2A)

The chromosome number are counted to be 2n=22 (Fig. 1A). This species was reported to have n=11 chromosomes by Toyohuku (1935) and Soeda (1944). Chromosomes show a gradual variation in length from about 2.2 μm to 1.2 μm, and total length is 37.5 μm. The longest and the next pairs of chromo-

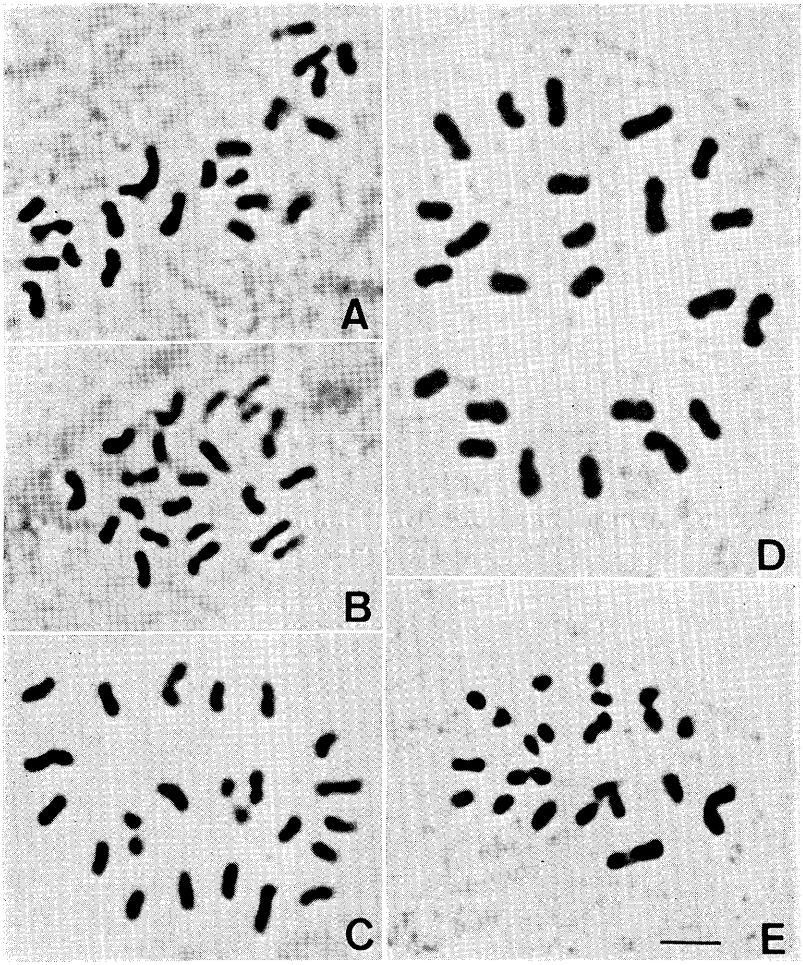

Fig. 1. Photomicrographs of chromosomes at somatic metaphase in five taxa of *Sedum*. A: *S. pluricaule* ssp. *pluricaule* var. *yezoense*, 2n=22. B: *S. pluricaule* ssp. *hidakanum*, 2n=22. C: *S. verticillatum*, 2n=22. D: *S. sordidum*, 2n=24. E: *S. viride*, 2n=21. Bar represents 3 μm.

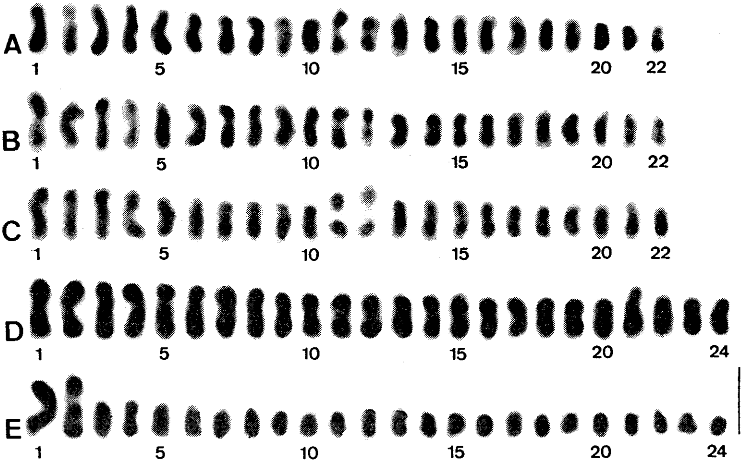

Fig. 2. Photomicrographs of alignment of somatic chromosomes. A: *S. pluricaule* ssp. *pluricaule* var. *yezoense*. B: *S. pluricaule* ssp. *hidakanum*. C: *S. verticillatum*. D: *S. sordidum*. E: *S. viride*. Bar indicates 3 μm.

somes are classified as the submedian type and the remaining 9 pairs are of median centromer. The chromosome complement was categorized to be a symmetric karyotype in arm ratio (Tanaka 1980). Satellite chromosomes are not observed. Severable chromosomes in centromere are observed on a pair of No. 6 (Fig. 2A).

2) *S. pluricaule* ssp. *hidakanum* (Tatewaki) Nosaka, 2n=22 (Fig. 1B & 2B)

The chromosome number is counted to be 2n=22 (Fig. 1B). This chromosome number is observed for the first time in this taxon. Chromosomes show a gradual variation in length from about 2.3 μm to 1.3 μm, and total length is 38.2 μm. Two pairs of the chromosomes, Nos. 2 and 4, are classified as the submedian type and the remaining 9 pairs are of median centromer. Severable chromosomes in centromere are observed on a pair of No. 6 (Fig. 2B).

3) *S. verticillatum* L., 2n=22 (Fig. 1C & 2C)

The chromosome number is counted to be 2n=22 (Fig. 1C). This species was reported to have n=11 and 2n=22 chromosomes by Toyohuku (1935), Soeda (1944), 2n=22, 46 and 92 by Funamoto & Yuasa (1986) and n=ca. 48 by Uhl & Moran (1972). Chromosomes show a gradual variation in length from about 2.4 μm to 1.4 μm, and total length was 38.4 μm. Most of the chromosomes are classified as the median or submedian type. Satellite chromosomes are not observed. Severable chromosomes in centromere are observed on a pair of No. 6 (Fig. 2C).

4) *S. sordidum* Maxim., 2n=24 (Fig. 1D & 2D)

The chromosome number is counted to be 2n=24 (Fig. 1D), which agrees with previous reports (Toyohuku 1935, Soeda 1944, and Uhl & Moran 1972). Chromosomes show a gradual variation in length from about 2.7 μm to 1.6 μm, and total length is 49.5 μm. Two pairs of the chromosomes, Nos. 2 and 3, were classified as the submedian type and the remaining 10 pairs were of median centromeres. Satellites were observed on the short arms of the 21th and 22th chromosomes (Fig. 2D).

5) *S. viride* Makino, 2n=24 (Fig. 1E & 2E).

The chromosome number is counted to be 2n=24 (Fig. 1E). This species was reported on the n=12 chromosomes by Uhl & Moran (1972), previously. Among the 24 chromosomes, two longest chromosomes (the 1st and 2nd) are clearly distinguished. They varies in length about 2.8 μm and 2.7 μm. The other twenty-two chromosomes (the 3rd-24th) showed a gradual variation in length from about 1.7 μm to 1.0 μm. Total length of 24 chromosomes was 32 μm. This species shows a bimodal variation in chromosome length. All chromosomes had a median centromere and satellites are not observed. Second constrictions are observed on the interstitial region of the long arms of the longest chromosome pair (Fig. 2E).

Discussion The somatic chromosome numbers of *Sedum pluricaule* ssp. *hidakanum* was counted for the first time in this study. Those of the other four taxa observed in this study agree with previous reports. Three taxa of 2n=22 chromosomes were found to have the similar karyotypes (in each chromosome length and total one), but two taxa of 2n=24 chromosomes are different from each other in the karyotypes.

On the variation in chromosome length, *S. viride* is found to be a bimodal change, and the other four taxa gradual one. The chromosomes of the five taxa have median or submedian centromeric positions. The chromosome complements are categorized to be a symmetric karyotype in arm ratio.

Baldwin (1937) described karyotypes of five species of the section Telephium. *S. tatarinowii* (2n=20), of which one chromosome pair is much larger than any of the other members of the complement, shows a bimodal variation in chromosome length, but the other four species of *S. ewersii* (2n=22) and its variety *homophyllum* (2n=22), *S. populifolium* (2n=22), *S. sieboldii* (n=25, 2n=50), and *S. maximum* (n=12, 24, 2n=24, 48) have a gradual variation. The chromosomes of five species are medianly or submedianly constricted. *S. sieboldii* has one pair of satellite chromosomes.

In this study, one chromosome pair of *S. viride* is much longer than any of the other members of the complement as *S. tatarinowii*. *S. pluricaule* ssp. *pluricaule* var. *yezoense* and *S. pluricaule* ssp. *hidakanum* have similar karyotypes. But, two pairs, Nos. 1 and 4, are of different centromeric positions.

Three taxa of 2n=22 chromosomes have the severable chromosomes in centromere on a pair of No. 6. These chromosomes are not observed in two taxa of 2n=24.

On the differentiation of basic number in the section Telephium, it may be considered that the reciplocal translocations and elimination of the non-centromeric chromosomes arise in two pairs chromosomes in basic number x=12, to result in the basic number x=11 (Fig. 3).

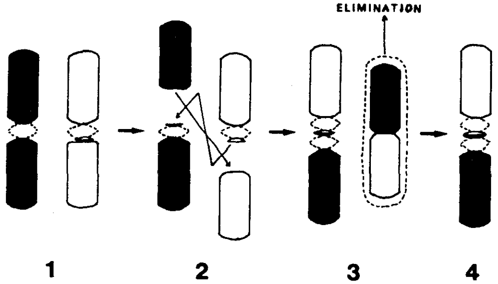

Fig. 3. Diagrams showing the hypothetic differentiation of basic number.

Baldwin (1937) said about basic number that "12 (or 6) is the primary basic number, and 10 and 11 are the secondary basic number in section Telephium". Our study supports Baldwin's statement.

It is concluded that Japanese diploid species in the section Telephium are at least classified into the following three groups karyologically. 1) Gradual variation in the chromosome length with basic number x=11, 2) Gradual variation in the chromosome length with basic number x=12, and 3) Bimodal variation in the chromosome length with basic number x=12.

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エゾミセバヤ (*Sedum pluricaule* ssp. *pluricaule* var. *yezoense*), ヒメミセバヤ (*S. pluricaule* ssp. *hidakanum*), ミツバベンケイソウ (*S. verticillatum*), チチッパベンケイソウ (*S. sordidum*), およびアオベンケイソウ (*S. viride*) の5 taxaについて核型分析を行なった。体細胞染色体数はエゾミセバヤ，ヒメミセバヤ，およびミツバベンケイソウが $2n=22$，チチッパベンケイソウとアオベンケイソウが $2n=24$ であった。動原体の位置は5 taxaとも中部あるいは次中部に位置し，腕比において対称的であった。エゾミセバヤ，ヒメミセバヤ，およびミツバベンケイソウはそれぞれの染色体長および総染色体長ともによく似ていた。しかし，チチッパベンケイソウとアオベンケイソウにおいては違いが認められた。染色体の長さの変異はアオベンケイソウが二相的であったが，他の4 taxaは勾配的であった。染色体数 $2n=22$ の3 taxaは動原体付近で離れ易い染色体がともに6対目に観察された。付随体はチチッパベンケイソウのみで観察された。また，アオベンケイソウの最大染色体対の長腕介在部に二次狭窄が観察された。

以上のことより日本産ベンケイソウ節（亜属）の二倍体種は細胞学的に見て少なくとも3グループに分けられた。1) 染色体数 $2n=22$，染色体の長さは勾配的な変化。2) 染色体数 $2n=24$，染色体の長さは勾配的な変化。3) 染色体数 $2n=24$，染色体の長さは二相的な変化。なお，$2n=22$ は $2n=24$ から分化したと考えられる。